

# Nano Materials in Cement and Construction Industry

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Abstract : Nanotechnology is one of the most active research areas with both novel science and useful applications that has gradually established if in the past two decades. Expenditure on nanotechnology research is significant; however, the research is continuously moving forward motivated by immediate profitable return generated by high value commercial products. The Architecture, Engineering, and Construction (A/E/C) industry might accommodate broad applications of nanotechnology and nanomaterials. It has been demonstrated that nanotechnology generated products have many unique characteristics, and can significantly fix current construction problems, and may change the requirement and organization of construction process.

This paper examines and documents applicable nanotechnology based products that can improve the overall competitiveness of the construction industry. The areas of applying nanotechnology in construction will be mainly focused on: (1) lighter and stronger structural composites, (2) low maintenance coating, (3) better properties of cementitious materials, (4) reducing the thermal transfer rate of fire retardant and insulation, and (5) construction related nano-sensors.

**Keywords:** Nano-technology, Nanomaterials, Construction

## 1. Introduction

Nanotechnology, introduced almost half century ago, is one of the most active research areas with both novel science and useful applications that has gradually established in the past two decades. The evolution of technology and instrumentation as well as its related scientific areas such as physics and chemistry are making the research on nanotechnology aggressive and evolutionary. Not surprisingly, it is observed that expenditure on nanotechnology research is significant. The U.S. National Nanotechnology Initiative (NNI) expenditures exceed \$1 billion each year, with the President's 2008 budget for NNI at \$1.5 billion. However, the research is mainly moving forward motivated by immediate profitable return generated by high value commercial products (Dhir et al., 2005). According to a study by the Canadian Program on Genomics and Global Health (CPGGH), nanotechnology in construction ranked 8 of 10 applications that most likely have impact in the developing world (ARI News, 2005). Although currently behind other areas such as water treatment and remediation, the Architecture, Engineering, and Construction (A/E/C) industry might accommodate broad applications of nano-products. Nanotechnology products can be used for design and construction processes in many areas. It is provided to demonstrate that nanotechnology generated products have many unique characteristics, and can significantly fix current construction problems, and may change the requirement and organization of construction process. This paper examines and documents applications of nanotechnology that can improve the overall competitiveness of the construction industry.

The data and information collected is from current literature and researches and focus on nanotechnology basics and applications of nanotechnology and nonmaterial in construction areas. The purpose is to point out clearcut direction among the nanotechnology development areas where the construction process would immediately harness nanotechnology, by specifying clear recommendations. The information would be beneficial to both construction engineering education and research.

## 2. Nanotechnology Basics

Nanotechnology is the creation of materials and devices by controlling of matter at the levels of atoms, molecules, and supramolecular (nanoscale) structures (Roco *et al.*, 1999). In other words, it is the use of very small particles of materials to create new large scale materials (Mann, 2006). Although more thorough

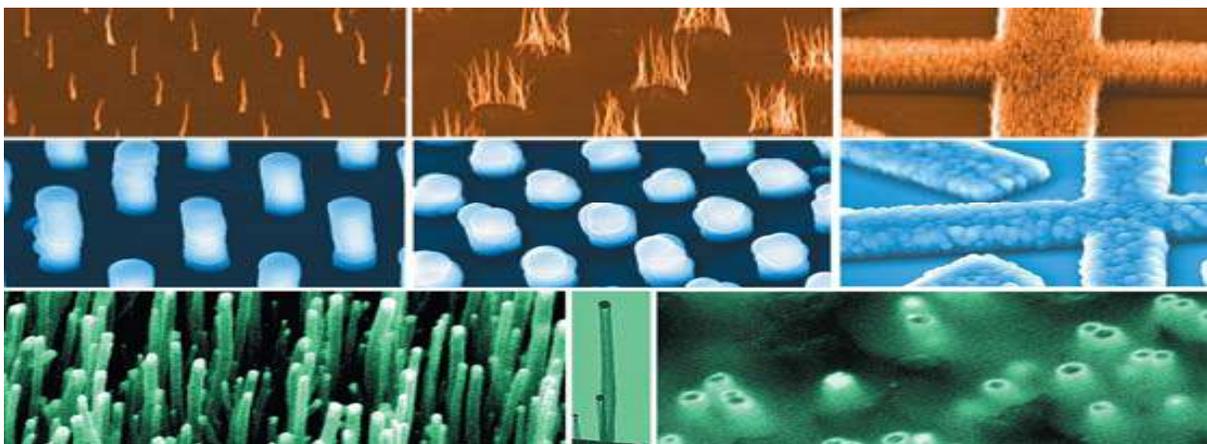
definitions were used by some researchers as well, the key is the size of particles because the properties of materials are dramatically affected under a scale of the nanometer (nm),  $10^{-9}$  meter (m). To better understand the difference among various scales,

Table I shows the categories of scales and its related topics (Balaguru, 2005).

Scales(Meter)	Relates Topics (not inclusive)
10-12	Quantum Mechanics
10-9	Molecular Dynamics <b>Nanomechanics</b> Molecular Biology Biophysics
10-6	Elasticity Plasticity Dislocation
10-3	Mechanics of Materials
10-0	Structural Analysis

**Table 1: Scales vs. Topic Areas**

Actually, nanotechnology is not a new science or technology. It was believed first introduced by Richard P. Feynman in his lecture at the California Institute of Technology in 1959. However, the research on this topic has been very active only in recent two decades. This is because the development and application of nanotechnology are relying on the development of other related science and technology such as physics and chemistry that are commonly new to break through at that time. Most promising developments of nanotechnology are fullerene (a new form of carbon, C<sub>60</sub>) and carbon nanotubes (Sobolev and Gutierrez, 2005). Nanotubes, illustrated by Figure 1 and Figure 2, are “a grapheme sheet rolled into a cylinder with specific alignment of hexagonal rings.” (Sobolev and Gutierrez, 2005). Understanding and development of nanoscale structures change the traditional process of producing and applying construction materials and elements. The new features of construction materials and elements accordingly change the material usage and force and resistance calculations of project design and its related field construction operation and management.



**Figure 1: Nanotubes**

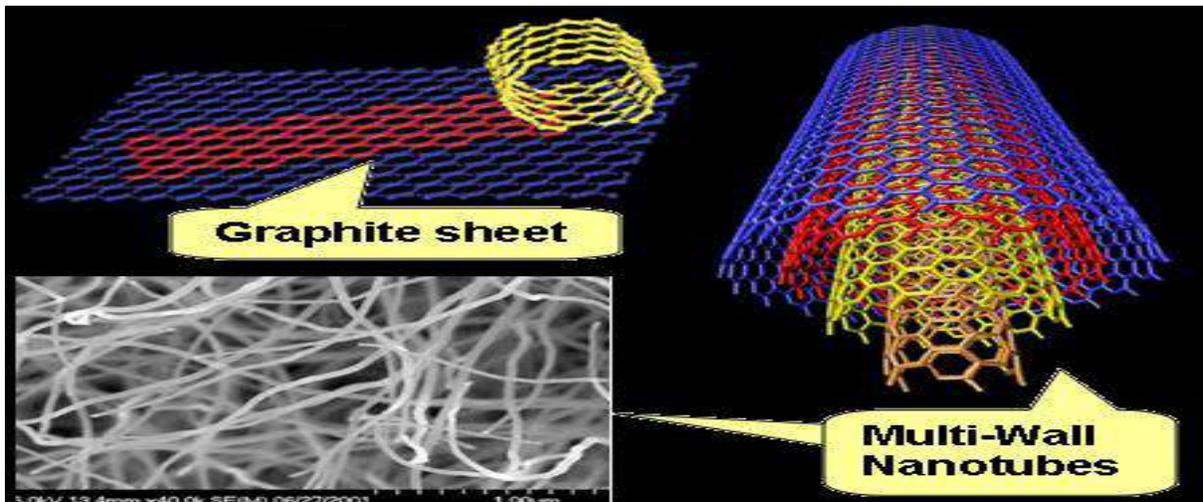


Figure 2: Graphite sheet of nanotubes

### 3. Application of Nanotechnology in Construction

Nanotechnology can be used for design and construction processes in many areas since nanotechnology generated products have many unique characteristics. These characteristics can, again, significantly fix current construction problems, and may change the requirement and organization of construction process.

These include products that are for:

- Lighter and stronger structural composites
- Low maintenance coating
- Improving pipe joining materials and techniques.
- Better properties of cementitious materials
- Reducing the thermal transfer rate of fire retardant and insulation
- Increasing the sound absorption of acoustic absorber
- Increasing the reflectivity of glass.

#### 3.1 Concrete

Concrete is one of the most common and widely used construction materials. Its properties have been well studied at macro or structural level without fully understanding the properties of the cementitious materials at the micro level. The rapid development of new experimental techniques makes it possible to study the properties of cementitious materials at micro/nano-scale. Research has been conducted to study the hydration process, alkali-silicate reaction (ASR), and fly ash reactivity using nanotechnology (Balaguru, 2005). The better understanding of the structure and behavior of concrete at micro/nano-scale could help to improve concrete properties and prevent the illness, such as ASR.

Addition of nanoscale materials into cement could improve its performance. Li (2004) found that nano-SiO<sub>2</sub> could significantly increase the compressive for concrete, containing large volume fly ash, at early age and improve pore size distribution by filling the pores between large fly ash and cement particles at nanoscale. The dispersion/slurry of amorphous nanosilica is used to improve segregation resistance for self-compacting concrete (Bigley and Greenwood, 2003). It is also been reported that adding small amount of carbon nanotube (1%) by weight could increase both compressive and flexural strength (Mann, 2006).

Cracking is a major concern for many structures. University of Illinois Urbana-Champaign is working on healing polymers, which include a microencapsulated healing agent and a catalytic chemical trigger (Kuennen, 2004). When the microcapsules are broken by a crack, the healing agent is released into the crack and contact with the catalyst. The polymerization happens and bond the crack faces. The selfhealing polymer could be especially applicable to fix the microcracking in bridge piers and columns. But it requires costly epoxy injection.

#### 3.2 Structural Composites

Steel is a major construction material. Its properties, such as strength, corrosion resistance, and weld ability, are very important for the design and construction. FHWA together with American Iron and Steel Institute and the U.S. Navy started to develop new, low carbon, high-performance steel(HPS) for bridges in 1992(Kuennen,

2004). The new steel was developed with higher corrosion-resistance and weld ability by incorporating copper nanoparticles from at the steel grain boundaries.

Sandvik Nanoflex<sup>TM</sup> is new stainless steel with ultra-high strength, good formability, and a good surface finish developed by Sandvik Nanoflex Materials Technology. Due to its high performance, Sandvik Nanoflex<sup>TM</sup> is suitable for application where requires lightweight and rigid designs. For certain applications, the components could be even thinner and lighter than that made from aluminium and titanium due to its ultra-high strength and modulus of elasticity. Its good corrosion and wear resistance can keep life-cycle costs low. Attractive or wear resistant surfaces can be achieved by various treatments (Sandvik Nanoflex Materials Technology).

MMFX2 is nanostructure-modified steel, produced by MMFX Steel Corp. Compared with the conventional steel; it has a fundamentally different microstructure- laminated lath structure resembling “plywood”. This unique structure provides MMFX2 steel with amazing strength (three times stronger), ductility, toughness, and corrosion resistance. Due to the high cost, the stainless steel reinforcement in concrete structure is limited in high risk environments. The MMFX2 steel could be an alternative because it has the similar corrosion resistance to that of stainless steel, but at a much lower cost (MMFX Steel Corp.).

### **3.3 Coating**

The coatings incorporating certain nanoparticles or nanolayers have been developed for certain purpose. It is one of the major applications of nanotechnology in construction. For example, TiO<sub>2</sub> is used to coat glazing because of its sterilizing and anti-fouling properties. The TiO<sub>2</sub> will break down and disintegrate organic dirt through powerful catalytic reaction. Furthermore, it is hydrophilic, which allow the water to spread evenly over the surface and wash away dirt previously broken down. Other special coatings also have been developed, such as anti-graffiti, thermal control, energy saving and anti-reflection coating.

### **3.4 Nanosensors**

Nano and micro-electrical mechanical systems (MEMS) sensors have been developed and used in construction to monitor and/or control the environment condition and the materials/structure performance.

One advantage of these sensors is their dimension. Nano-sensor ranges from 10<sup>-9</sup> m to 10<sup>-5</sup>m. The micro sensor ranges from 10<sup>-4</sup> to 10<sup>-2</sup> m (Liu *et al.*, 2007). These sensors could be embedded into the structure during the construction process.

Smart aggregate, a low cost piezo-ceramic-based multi-functional device, has been applied to monitor early age concrete properties such as moisture, temperature, relative humidity and early age strength development (Saafi and Romine, 2005; Song and Mo, 2008). The sensors can also be used to monitor concrete corrosion and cracking.

The smart aggregate can also be used for structure health monitoring. The disclosed system can monitor internal stresses, cracks and other physical forces in the structures during the structures' life. It is capable of providing an early indication of the health of the structure before a failure of the structure can occur.

## **4. Conclusion**

While nanotechnology based construction products provide many advantages to the design and construction process, the production of these products, however, require a lot of energy. Also, the nanotubes might cause a lung problem to construction workers. In other words, it creates an environmental challenge to the construction industry as well. Sustainability and environmental issues caused by growing economic development has gained intensive statewide and worldwide attention.

Since the construction industry is heavily involved in the economic development and consumes great amount of resources and energy, its impact on environment is significant. Therefore, it is necessary and urgent to regulate the construction and its related performance to sustainable manners. The nano-technology becomes a double-edge sword to the construction industry. More research and practice efforts are needed with smart design and planning, construction projects can be made sustainable and therefore save energy, reduce resource usage, and avoid damages to environment. It is necessary to establish a system to identify the environmentally friendly and sustainable of construction nanomaterials and to avoid the use of harmful materials in the future.

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